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**ORIGINAL ARTICLE**

# The Role of Shear-Wave Elastography in Assessment of Inflammatory Breast Lesions

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## ABSTRACT

**Background:** Mastitis, abscesses, and inflammatory breast cancer are among the benign and malignant disorders that fall under inflammatory breast lesions. Accurate diagnosis is difficult since these illnesses frequently appear with overlapping clinical and radiological characteristics. Shear-wave elastography (SWE) is a new ultrasound-based imaging technique that measures the speed at which shear waves move through tissue to quantitatively evaluate tissue stiffness. Therefore, our goal was to analyze how shear-wave elastography may be used to diagnose inflammatory breast lesions and distinguish between malignant origins of these lesions.

**Methods:** This prospective study, which involved 36 patients, was carried out at our University Hospital's Radiology Department's Women Imaging Unit after referrals from the breast surgery clinic and outpatient clinic. Shear Wave Elastography was performed following breast ultrasound.

**Results:** Above a cut off 2.95, SWV demonstrated an AUC of 0.953, level of sensitivity 85.7%, specificity 89.7%, PPV 66.7%, NPV 96.3%, and accuracy 88.9% when used to distinguish between benign and malignant conditions. With a kappa (κ) of 0.680, the final diagnosis from SWV and biopsy revealed a high degree of agreement on the classification of the lesion as either benign or malignant. With a kappa (κ) of 0.789, HHUS and mammography demonstrated a high degree of agreement in classifying lesions as either benign or malignant.

**Conclusion:** SWE imaging may be useful to improve the diagnostic confidence in an indeterminate BI-RADS 3 or 4a lesion if ultrasonography features are questionable, and it aids in differentiating between benign and malignant breast lesions if biopsy is still recommended.

**Keywords:** Shear-wave elastography; Inflammatory breast lesions; Breast imaging; Tissue stiffness.

## INTRODUCTION

Inflammation caused by underlying breast cancer, non-infectious inflammation, and common benign infections are only a few of the many underlying causes of inflammatory breast illnesses. The diagnostic conundrum is exacerbated by the fact that benign mastitis and breast cancers can occasionally have similar clinical and radiological characteristics, making it challenging to differentiate between the two [1].

Mastitis, which is defined as inflammation of breast parenchyma, can be a crippling condition with long-term morbidity. It frequently manifests pain, swelling, warmth, erythema, and fever [2]. A wide range of additional vague symptoms could also be present, which could cause a delayed diagnosis and ineffective therapy [3]. The rule in the majority of mastitis cases is complete resolution. A biopsy should be carried out and inflammatory cancer should be ruled out if antibiotic treatment is unsuccessful after ten days [4].

Because of their poorer prognosis and the significant differences in how they are managed, breast malignancies, namely inflammatory breast cancers, need to be tested out and distinguished from benign mastitis [1].

The American College of Radiology created the language for the Breast Imaging Reporting and Data System (BI-RADS) [5]. Which additional clinical action should be performed is indicated by the unique BI-RADS assessment category. BI-RADS 3 lesions are most likely benign, and short-term monitoring is advised. However, approximately 3% of these lesions are finally confirmed as malignant, which means that many patients receive a delayed cancer diagnosis [6].

Biopsies and fine-needle aspiration cytology (FNAC) should be considered because the probability of cancer for BI-RADS 4 lesions is low to moderate (3%–94%). A significantly greater percentage of patients with BI-RADS category 4 undergo invasive diagnostic procedures that might not be required if improved imaging methods were available for precise diagnosis confirmation, and 15% of outcomes are histologically malignant [7].

For inflammatory malignant tumors to be successfully managed, early diagnosis is essential. According to the standardized Breast Imaging Reporting and Data System (BI-RADS) terminology, conventional ultrasonography (US) is now a key component of diagnostic approaches [5].

Certain conditions can change the tissues' intrinsic elastic properties; one pathophysiologic process affecting the tissues' elasticity is neoplasm [8].

In general, breast lesions that are more rigid and immovable indicate cancer. An approach to determining tissue stiffness that is more objective is shear wave elastography (SWE), was created based on this idea [8].

Shear Wave Elastography (SWE) produces better-quality images than US or mammography for the identification of breast cancer, per research and a meta-analysis by Sadigh et al. [6]. This can assist prevent breast biopsies by increasing specificity and reducing false-positive outcomes [9, 10].

Enhancing the differential diagnosis of breast lesions is becoming more common with Shear Wave Elastography (SWE), a more modern mode that is accessible in the newest generation of ultrasound equipment and provides superior quality B mode ultrasonography. The Shear Wave Elastography (SWE) approach is traditionally less operator-dependent, yet excessive pressure on the probe may cause considerable fluctuation (kPa elasticity readings or falsely exaggerated shear wave measurement velocities) [9].

Three modes are offered in Shear Wave Elastography: velocity measurements can be recorded in meters per second or as a color velocity map, or a color map can be created. Data from the literature indicates that malignant lesions are more likely to have lesion velocities of more than 4.5 m/s. The shear wave elastography approach cannot be used to calculate a significant elasticity value in a pure cyst because shear waves are not produced when the ultrasound beam encounters a cyst. This kind of artifact results in a signal deficit that facilitates diagnosis in a pure cyst [10].

Elasticity is measured in kPa or m/s, and images are shown on a real-time color map with an adjustable elasticity scale displayed in kPa, with the default setting for the breast at 180 kPa, in accordance with the guidelines and recommendations for the clinical use of Shear Wave Elastography (SWE) published by the World Federation for Ultrasound in Medicine and Biology (WFUMB). The operator can assess elasticity and elasticity ratios on an area of interest (ROI) once the acquisition is complete (on a frozen image). The elasticity threshold for benign or malignant tumors varies, according to several research. According to a recent study including a sizable patient population, readings below 60 kPa linked to an oval-shaped breast lesion were reliable indicators of a benign lesion. With this cut-off, specificity increased (from 77.4% to 69.4%) without sacrificing sensitivity when compared to B mode. Typically, malignant lesions have pressures more than 60 kPa [11].

Improving the characterisation of benign and malignant breast lesions is the primary goal of breast shear wave elastography (SWE). Numerous studies have demonstrated that the BI-RADS score can be raised by using SWE characteristics in addition to ultrasound measurements. When a malignant lesion appears to be highly deformable, it is imperative to prevent a false positive, even if SWE can be helpful in characterizing a cystic content without the requirement for fine needle aspiration. However, it seems to be helpful for malignant tumors that show up on B mode as benign lesions that are not very deformable on SWE. It appears that solid BI-RADS 3 or 4a lesions are the best candidates for application. Prior to biopsy, SWE can also boost the operator's confidence in their diagnosis [12].

Therefore, a prospective study was designed to ascertain if the combination of traditional B-mode ultrasonography and SWE enhances diagnostic performance and boosts confidence when examining women with suspected inflammatory breast lesions in everyday clinical practice.

## METHODS

Thirty-six patients participated in the current prospective study. After breast ultrasonography, shear wave elastography was done to assess its potential influence on a precise diagnosis and the ensuing management planning guidance. The Women Imaging Unit at the Radiology Department of our University Hospital, which was referred by the outpatient clinic and breast surgery clinic, was the site of this study from January to June 2024. The patients ranged in age range from 18 to 90 years, with a mean age of 54.47 (±18.32 SD).

The study was approved by ethical committee of Faculty of Medicine, our University (IRB number 10991-2-8-2023). An informed consent was obtained from all patients. The study was carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans.

***Inclusion Criteria:***

- Patients who exhibit the clinical manifestations of mastitis, including hotness, redness, and localized or widespread breast enlargement, with or without palpable breast masses and general constitutional symptoms.
- Individuals with probable inflammatory breast diseases who show up for an ultrasound examination.

***Exclusion Criteria:***

- Individuals who present with breast illness that is not inflammatory.

***Image Analysis:***

Two seasoned radiology consultants with 25 and 15 years of expertise in breast imaging and interventional procedures, respectively, oversaw the image analysis and ultrasound performance (both grayscale and SWE). For the masses found, the experts did an imaging-guided biopsy.

During the initial examination, the writers were blinded to the pathology results and to each other's analysis. A multidisciplinary discussion of cases with the referring physician took place at the final evaluation stage.

***Ultrasound Examination:*** B-mode ultrasonography was used to assess every subject. The ACUSON S2000/S3000 (Siemens) high-end ultrasound system, which includes a multi-frequency linear probe running at 6 to 15 MHz software and a combined autocorrelation approach, was used to do the examinations. The scanning approach includes both longitudinal and transverse real-time imaging of masses of concern. A split-screen imaging method (twin pictures) was employed for conventional US and SWE to provide comparable pictures that are best suited for accurate use in subsequent region of interest (ROI) and velocity (Vs) assessments.

The following should either be confirmed (+ve finding) or ruled out (-ve finding) in ultrasound reports:

• Edematous fat lobules that are echogenic.
The interstitial fluid.
• Collections that lack definition.
• Dilatation of the retroareolar duct system.
• The measurement of thicker skin (>2 mm).
• Examine masses to see whether they are solid or cystic.
• Cavities with abscesses.
• The size and condition of lymph nodes.

Shape, boundary, orientation, margin, echo pattern, posterior acoustic characteristics, and calcifications were all taken into consideration when evaluating the lesions. The final evaluation also considered the state of the surrounding tissue.

According to the American College of Radiology Breast Imaging Reporting and Data System (BI-RADS), lesions on B-mode ultrasound were classified as follows: Category 2 lesions were classified as benign, Category 3 lesions may be benign, Category 4 lesions may be concerning for malignancy, and Category 5 lesions may be strongly suggestive of malignancy.

***Shear-wave Elastography***

Every patient underwent a shear-wave elastography examination. The transducer with coupling gel was applied to the skin, and the mass under consideration was then focused upon to produce the images.

The tissue is exposed to an initial ultrasound pulse, also known as a push pulse or ARFI pulse, which causes a shear wave to form perpendicular to the ultrasonic beam. Dropping a stone (the push pulse) into a water pond is analogous to this. The shear waves are reflected in the ripples created. By tracking the tissue displacement brought on by the shear waves, the velocity of the shear wave passing through the tissue is determined using standard B-mode ultrasonic sampling procedures. The velocity of the shear wave through the tissues can be used to estimate the strain modulus, also known as Young's modulus. Higher shear wave velocities indicate stiffness, and vice versa. There is a clear correlation between the two. A lesion's stiffness can be expressed as the strain modulus in kilopascals (kPa) or as the Vs in m/s through the tissue. A few assumptions are made to determine the strain modulus, also known as Young's modulus [12]. Malignant lesions are more likely to have lesion velocities of more than 4.5 m/s [10].

SWE provides a quantitative assessment of the lesion stiffness, either in a greater field of view (FOV) with pixel-by-pixel color coding of the Vs (shear wave imaging) or in a site of interest (point quantification). The majority of systems let the user choose their preferred scale. Following the initial push pulse, the displacement of the tissue as the shear wave passes is detected and its velocity in a region of interest is reconstructed using tracking signal vectors. This can be shown as a quantitative depiction of shear wave speed or as a qualitative representation of elasticity. Both measurement in a narrow region of interest (ROI) and pixel-by-pixel evaluation (shear wave imaging) of a larger FOV using a color map are made possible by the SWE system. It takes a few seconds to resume imaging after a single image is captured. Shear wave signal identification is made more steady and less noisy by using tracking vectors with concentrated transmission.

***Final Diagnosis:***

Following the monitoring of the response to antibiotic medication or the acquisition of surgical or biopsy specimens that served as reference standards for histological diagnosis, the final diagnosis was made.

To further enhance the criteria for distinguishing between benign and malignant inflammatory lesions, the diagnosis from SWE was compared with the histopathologic diagnoses or follow-up for two weeks following antibiotic medication.

**Statistical analysis:**

IBM© SPSS© Statistics version 22 (IBM© Corp., Armonk, NY, USA) was used for statistical analysis. The mean, standard deviation, and range were used to express numerical data. Frequencies and percentages were used to convey the qualitative data. The relationship between qualitative variables was investigated using the chi-square test or Fisher's exact test. Sensitivity, specificity, positive predictive values (PPV), negative predictive values (NPV), and overall accuracy were calculated in respect to the gold standard (pathology) to evaluate the diagnostic techniques. The degree of agreement between two diagnostic techniques was assessed using the Kappa test. In every test, there were two tails. Less than 0.05 was considered a significant p-value.

## RESULTS

Descriptive data of studied cases according to Demographic data:

With a range of 18 to 90 years, the mean age of the cases under study was 54.47 (±18.32 SD). Based on their medical histories, 1 (2.8%) of them had a family history of breast cancer, 7 (19.4%) had a prior history of breast cancer, and 2 (5.6%) were pregnant. (**Error! Reference source not found.**1).

Descriptive data of studied cases according to management:

The management data indicates that 19 (52.8%) and 18 (50%) underwent color Doppler assessment and mammography, respectively. (Table S1).

Descriptive data of studied cases according to ultrasound outcome:

Among the cases under study, ultrasound results showed that 1 (2.8%) had BIRADS of 0, 6 (16.7%) had I, 6 (16.7%) had II, 19 (52.8%) had III, 3 (8.3%) had IV-A, 5 (13.6%) had IV-B, and 2 (5.6%) had V. Based on lesion classification, 26 (72.2%) had benign lesions and 10 (27.8%) had malignant ones. The range of sizes was 0.55 to 8.6 cm, with a mean of 2.21 (±1.69 SD) as indicated in (Table 2).

Descriptive data of studied cases according to SWE:

According to the data, the lesion's mean shear wave velocity was 3.15 (±2.47 SD) with a range of (1.2-9.1) m/s. (**Error! Reference source not found.**2).

Descriptive data of studied cases according to final diagnosis:

Among the cases studied, there were 30 (83.3%) benign and 6 (16.7%) malignant (Table 3).

Relation between SWV and Final Diagnosis:

There was a high statistically significant relation between SWV, and final diagnosis (Table S2).

Roc curve analysis for the use of SWV to discriminate between benign and malignant lesions:

Above 2.95, the SWV demonstrated an AUC of 0.953, level of sensitivity 85.7%, specificity 89.7%, PPV 66.7%, NPV 96.3%, and accuracy 88.9% in the differentiation between benign and malignant. (Table 4, Figure S1).

Agreement between SWV and final diagnosis regarding lesion classification:

With a kappa (κ) of 0.680, the final diagnosis from SWV and biopsy revealed a high degree of agreement on the classification of the lesion as either benign or malignant. With a kappa (κ) of 0.789, HHUS and mammography demonstrated a high degree of agreement in classifying lesions as either benign or malignant (Table 5).

Case study:

Case (1):

The patient is a 58-year-old woman with a recent (3months) lumpectomy for invasive ductal cancer in her left breast. The patient believes the surgical scar is increasing in size associated with tenderness. On mammography, a surgical scar is noted, but no previous postoperative films are available for comparison. The mammogram was classified as BI-RADS category 0, and an ultrasound was advised for further workup. On B-mode imaging there is a heterogeneous lesion hat is mostly hyperechoic with one adjacent hypo-echoic area. The lesion borders are indistinct. There is some internal blood flow noted on color Doppler imaging The lesion was classified as BI-RADS category 4B. On shear-wave imaging the lesion has a Vs of 7.6 m/s (175kPa) compared to a Vs of adjacent normal tissue of 1.7 m/s (9kPa). On a different shear-wave system. The lesion again has a central area of higher stiffness of Vs of 6.6 m/s (128kPa), with the remainder of the lesion having a stiffness of Vs 4.8 m/s (70kPa). The SWE findings on both machines are suggestive of malignancy. Final diagnosis was organizing fat necrosis. A vacuum-assisted 12-gauge core biopsy of the lesion was performed. The pathology was focal reactive fibrosis and organizing fat necrosis. SWE findings were dis-concordant with the histopathology result. (Figure 1).

**Case (2):**

The patient is 82-year-oldwoman presenting with an enlarged edematous left breast. The patient has a history of congestive heart failure and mild renal insufficiency. A mammogram demonstrated diffuse skin thickening and increased density in the left breast compared with the right. Ultrasound Findings revealed the skin thickness in the right breast is 2mm, whereas it measures between 6 and 8 mm in the left breast. There is diffuse edema within the fascial planes on the left. Power Doppler imaging demonstrates some blood flow within the edematous area. SWE revealed shear-wave imaging demonstrates the thickened skin has low Vs of 2.9 m/s (25kPa). Final diagnosis was benign skin thickening / edema. The patient underwent a skin biopsy, which demonstrated edema and lymphatic enlargement but no evidence of malignancy. SWE findings confirmed the data supplied by the conventional US and were concordant with the histopathology result (Figure 2).

**Case (3):**

A 68-year-old woman presented with a new palpable mass in the left breast. On diagnostic mammogram performed the same day a 3 cm irregular mass was identified. The mammogram was classified as BI-RADS category 0, and ultrasound was advised for further workup. Ultrasound Findings showed on B-mode imaging there is an irregular 4 cm complex-appearing mass corresponding to the palpable mass and mammographic abnormality. The mass has well defined borders and a hyperechoic rim. On color Doppler imaging, the lesion has adjacent blood flow but no internal blood flow. The lesion was classified as BI-RADS category 4A. SWE revealed on shear wave imaging; the lesion has a soft center (kPa 15) and a stiff rim (with a maximum kPa value of 63). Final diagnosis showed mastitis with abscess formation. The lesion was biopsied, and the pathology was chronic and acute mastitis with abscess formation, aspiration of the soft central area to confirm pus. SWE findings in mastitis are very soft areas representing abscess cavities and stiff areas representing inflammation and edema. Mastitis can have an elastographic appearance suggestive of malignancy. Mastitis is often false-positive for malignancy on SWE. It is rare that cancers have a very soft central area on elastography because liquefied necrosis is an uncommon finding in breast cancer (Figure S2).

**Table (1):** History characteristics of the study population

| Demographic data | Cases (n = 36) | |
|---|---|---|
| **Age (Years)** | | |
| **Min. – Max.** | 18.0 – 90.0 | |
| **Mean ± SD.** | 54.47 ± 18.32 | |
| **History data** | **No.** | **%** |
| **Family history of breast cancer** | 1 | 2.8 |
| **History of previous breast cancer** | 7 | 19.4 |
| **Pregnancy** | 2 | 5.6 |

**Table (2)**: Results of ultrasound examination and SWE measurements of the study population

| | Cases | |
|---|---|---|
| **BIRADs** | **No.** | **%** |
| **0** | 1 | 2.8 |
| **I** | 0 | 0.0 |
| **II** | 6 | 16.7 |
| **III** | 19 | 52.8 |
| **IV-A** | 3 | 8.3 |
| **IV-B** | 5 | 13.9 |
| **IV-C** | 2 | 5.6 |
| **V** | 0 | 0.0 |
| **Lesion classification by ultrasound** | **No.** | **%** |
| **Probably benign (BIRADS I-III)** | 26 | 72.2 |
| **Probably malignant (BIRADS IV-V)** | 10 | 27.8 |
| **Size (cm)** | | |
| **Min. – Max.** | 0.55 – 8.6 | |
| **Mean ± SD.** | 2.21 ± 1.69 | |
| **Shear wave velocity in the lesion** | | |
| **Min. – Max.** | 1.2 – 9.1 | |
| **Mean ± SD.** | 3.15 ± 2.47 | |

**Table (3):** Final diagnosis of the study population

| | Cases | |
|---|---|---|
| **Final Diagnosis** | **No.** | **%** |
| **Benign** | 29 | 80.6 |
| **Malignant** | 7 | 19.4 |

**Table (4):** Roc curve analysis for the use of SWV to discriminate between benign and malignant lesions

| | AUC | Cut-off value | Sens% | Spec% | PPV% | NPV % | Accuracy % |
|---|---|---|---|---|---|---|---|
| **SWV** | **0.953** | **2.95** | **85.7** | **89.7** | **66.7** | **96.3** | **88.9** |

**Table (5):** Agreement between SWV and final diagnosis regarding lesion classification

| SWV | Final diagnosis | | | | kappa (κ) |
|---|---|---|---|---|---|
| | Benign | | Malignant | | |
| | No. | % | No. | % | |
| **Benign** | **26** | **72.2** | **1** | **2.8** | **0.680** |
| **Malignant** | **3** | **8.3** | **6** | **16.7** | |

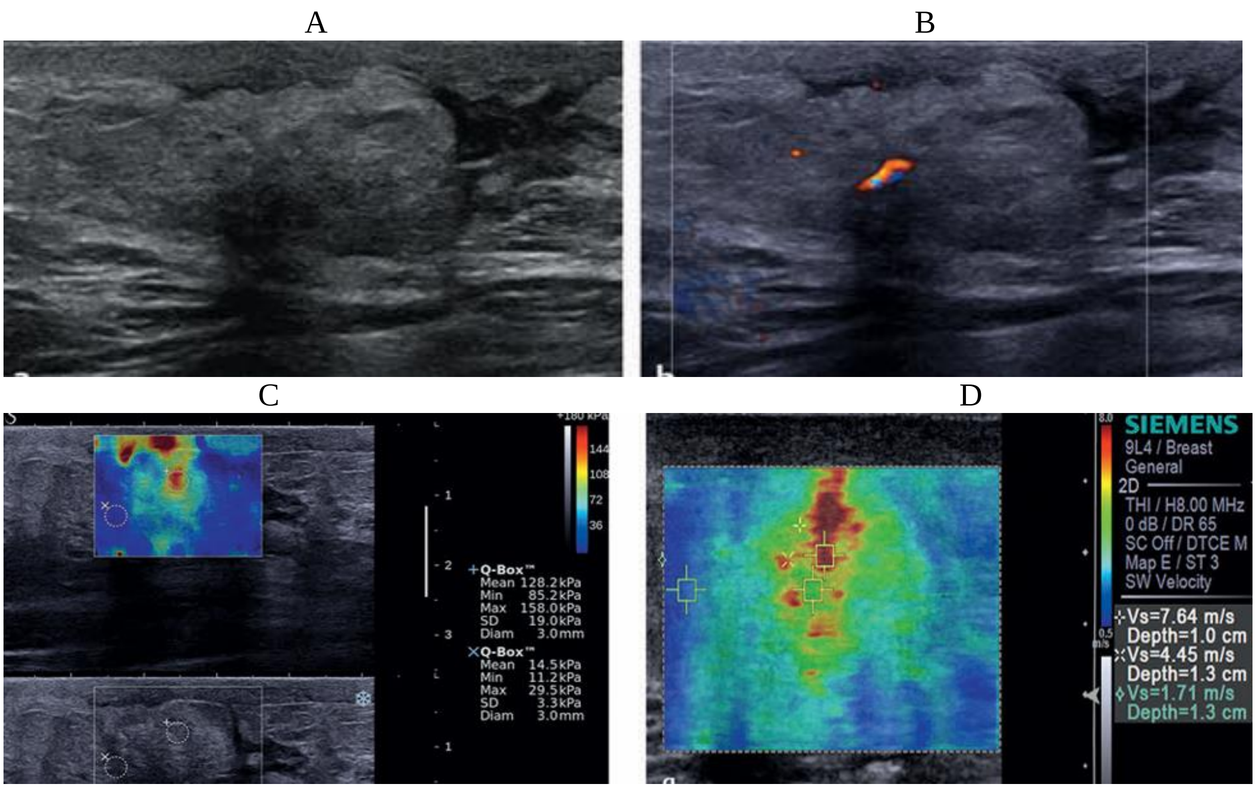


**Figure (1):** (A): The B-mode image of a 58-year-old with a recent lumpectomy for invasive ductal carcinoma (IDC) demonstrates a heterogeneous lesion that is mostly hyperechoic with an adjacent hypoechoic area. (B): There is some internal blood flow within the lesion on color Doppler evaluation. (C): On shear wave imaging the lesion has a high Vs of 7.6m / s (175kPa), suggestive of a malignant lesion. (D): Shear wave imaging on a different system has similar results to that in (C).

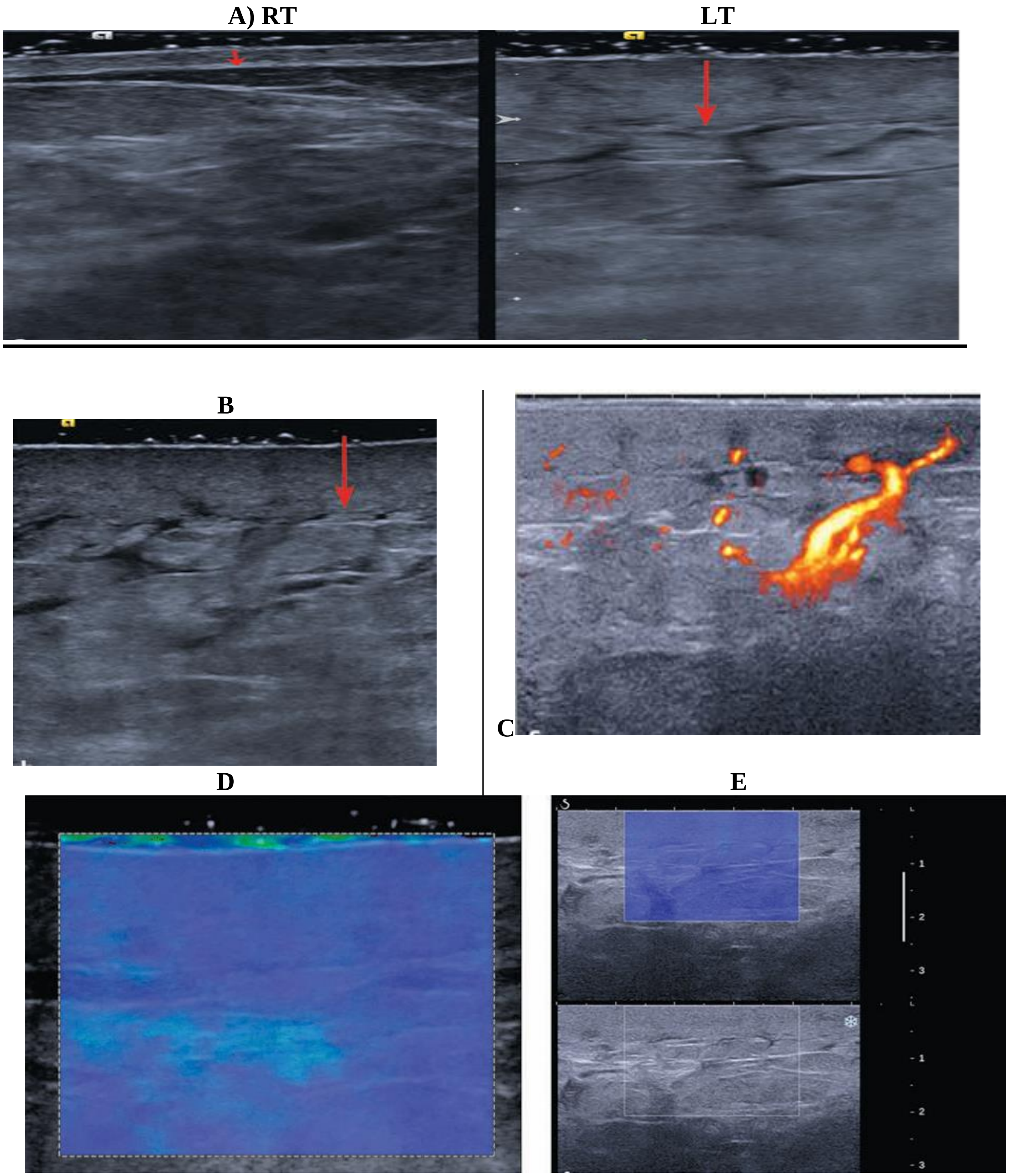


**Figure (2): (A):** Dual display of the patient's right and left breast comparing the skin thickness in a similar location to the breast. A red arrow marks the skin thickness in both images. The skin thickness measures 2mm in the normal breast and 8 mm in the abnormal breast. No focal lesion is identified Edema is also noted in the fascial planes in the abnormal breast. **(B):** B-mode image of the abnormal breast demonstrating the marked uniform skin thickening (red arrow) and the edema in the fascial planes.

**(C):** On power Doppler imaging there is generalized increased blood flow in the abnormal breast. **(D):** On shear-wave imaging the thickened skin codes soft with a Vs of 2.9 m/s (25kPa) No focal abnormality is noted within the thickened skin. **(E):** Shear-wave imaging on a different system provides the same results, a low Vs of the skin without focal abnormality.

## DISCUSSION

Mastitis is a broad term for breast inflammation that may or may not be associated with infection. All populations are susceptible to mastitis, regardless of breastfeeding status. Less than 10% of non-lactating women have this condition, but the reported incidence ranges from a few to 33% of lactating mothers [13]. Using clinical or imaging characteristics to differentiate acute mastitis from cancer, particularly inflammatory breast carcinoma (IBC), is still difficult [14].

Inflammatory breast cancer, a rare and aggressive form of invasive breast cancer, accounts for 2.5 percent of all cases of breast cancer. It is characterized by rapid progression and both distant and local metastases. Adding to the diagnostic conundrum, Because IBC is uncommon, it is commonly mistaken for mastitis or extensive dermatitis. [15].

Ultrasound is a dynamic, participatory modality. Compared to examining static images on a workstation, real-time scanning also offers the chance to evaluate lesions and allows for in-depth lesion analysis. It can be challenging to capture subtle irregular or obscure architectural distortions, aberrations, and margins in static photographs [16].

By improving the sensitivity and precision of traditional B-mode ultrasonography in the diagnosis of questionable (BIRADS III and IV) breast lesions, Shear Wave Elastography (SWE) can reduce the number of needless benign biopsies. [17].

We assessed 36 female patients with various breast conditions "between January 2024 to June 2024" for the current study. The patients ranged in age range from 18 to 90 years, with a mean age of 54.47 (±18.32 SD). All patients had diagnostic ultrasound and SWE.

Regarding historical data, there were two pregnant patients (5.6%), seven patients (19.4%) One patient (2.8%) had a family history of breast cancer, while another patient had a previous history of the disease.

In reference to additional tests, 19 (52.8%) had a color Doppler examination and 18 (50%) had a mammogram.

According to the American College of Radiology's (ACR) Breast Imaging Reporting and Data System (BI-RADS), our findings indicated that 25/36 (69.5%) patients had BIRADS II/III (benign), while 1/36 (2.8%) patients had BIRADS of 0. BIRADS IV-A, B, and C were present in the remaining 10/36 (27.8%) and were most likely malignant. The ultimate diagnosis for all BIRADS II/III patients was benign (100% NPV). BIRADS IV-B & C were present in 7 patients with malignant pathology (sensitivity=100%). In our study, three individuals were classified as BIRADS IV (false positive): one with fat necrosis, one with a breast abscess, and the final one with a complicated cystic lesion (large duct papilloma). Overall, there were 10 likely cancerous patients (27.8%) and 26 likely benign patients (72.2%) as the US specificity and accuracy were 89.6% and 88.8%, respectively.

According to our findings, the lesion's mean shear wave velocity, as determined by Shear-Wave Elastography, was 3.15 (±2.47 SD) with a range of (1.2-9.1) m/s. There were differences in velocities based on pathology and velocities for each diagnosis.

With respect to Shear-Wave Velocities and Final diagnostic, our findings indicated that

26 patients had a SWV below 3.7, 3 patients had velocities above 3.7 (false positive), 1 patient had a complicated cyst, and 30/36 (83.3%) patients had a benign final diagnostic. The SWI is not color coded. One patient had breast abscess (4.5 m/s), one had fat necrosis (7.2 m/s), and the final patient had big duct papilloma (6 m/s). The final diagnosis for the remaining 6 out of 36 patients (16.7%) was malignant; SWE's specificity and accuracy were 89.7% and 88.9%, respectively.

The ideal cut-off value for benign lesions, as indicated by the receiver operating characteristic (ROC) curve, was 2.95; for malignant lesions, the AUC was 0.953 below 2.95. This cut-off value was associated with 88.9% accuracy, 85.7% sensitivity, 89.7% specificity, 66.7% PPV, and 96.3% NPV. According to our findings, there was a considerable correlation between SWV and the final biopsy diagnosis, indicating a high degree of agreement with respect to the classification of the lesion as either benign or malignant, with Kappa (κ) 0.680.

In the work conducted by Schaefer which used the SWE approach to examine 370 individuals with lesions less than 2 cm (39% malignancies). When elastography was included, the sensitivity and specificity of the BI-RADS score increased from 83.9% and 68.3% to 90.3% and 87.8%, respectively. Schaefer et al. [18] demonstrated sensitivity of 96.0 percent and specificity of 76% in a different investigation of 193 lesions with a cut-off of 3.4. They suggested that SWE be utilized in addition to B mode ultrasound. [19].

According to a study by Tozaki et al. [20], a 3.6 m/s cut-off was found to have a 91% sensitivity and an 80.6% specificity in distinguishing benign from malignant lesions in a cohort of 161 masses, including 43 malignancies. Our results are consistent with that study.

Barr et al. [12] Based on an in-person analysis of 112 lesions, including 62 malignancies, a velocity score of 2.20 m/s offers a sensitivity of 94% and a specificity of 84%.

According to Itoh et al., [21] SWE had 86.5% sensitivity, 89.8% specificity, and 88.3% accuracy, compared to 71.2% sensitivity, 96.6% specificity, and 84.7% accuracy for standard US. They concluded that SWE performed nearly as well as traditional US in terms of diagnosing breast lesions.

Parajuly et al. [22] They concluded that SWE was better than B mode sonography in determining the type of breast lesions because its accuracy (95.8%), sensitivity (98.6%), specificity (96.0%), and positive predictive values (94.5%) were higher than those of B mode sonography (90.6%, 91.4%, 90.0%, and 86.5%, respectively).

The highest value of Vs for SWE in several studies varies from 4.1 m/s (50 kPa) to 5.2 m/s (80 kPa). These tests were carried out using "a light touch," yet there was no control over precompression. An elevated cutoff value of this range can be readily explained by the precompression effect. Additional well-controlled precompression investigations are required. It has also been proposed that a lesion's surrounding ring of high Vs is a sign of malignancy. Even in benign lesions, precompression will result in the formation of the ring, so caution is required. When there is a soft-to-hard tissue interface, the acoustic radiation force impulse (ARFI) may interact with boundary effects to produce this ring [23].

Overall, these several investigations found that SWE increased the specificity of conventional ultrasound and demonstrated the capability of reclassifying masses that were initially assigned the BI-RADS 3 and 4a classification. The BI-RADS classification and SWE score together seem to provide a higher sensitivity for diagnosing malignancy, and the elastography score cannot be used in isolation from the BI-RADS score.

It should be noted that when tissue deformation is too little, elasticity in the shear-wave elastography technique can occasionally not be determined. Large, extremely stiff infiltrative tumors may exhibit this [24]. High attenuating regions, such the deepest portion of scirrhous tumors, are inaccessible to the ultrasonic beam in this situation. SWE mode does not display colors, while ARFI mode displays a register speed in m/s instead of the XXX value. These characteristics should not be misinterpreted because benign lesions may have low value. In lesions where the tissue does not shake sufficiently or where the shear wave's amplitude is too small and hence lost in background noise, the devices are unable to measure the elasticity values [25].

On B mode ultrasonography, non-viscous cysts can show up as black patches in the hypoechoic region because they don't produce shear waves. Nonetheless, shear waves with low values can be captured when the cyst has a limited degree of viscosity.

Sousaris & Barr [26] said that out of the more than 400 breast cancer cases they had seen on SWE, only one—a case of lung cancer that had spread to the breast—had a soft center. In regions of necrosis, necrotic breast tumors typically have rigid fibrotic tissue rather than soft material. Mastitis should therefore be considered as a differential factor when utilizing SWE, particularly in cases when a lesion has a soft center region and firm boundaries.

According to our findings, combining US and SWE produced the best outcomes. With combined US and elastography, only three (false positive) patients—fat necrosis, breast abscess, and big duct papilloma—were identified as malignant. Accuracy, specificity, and sensitivity were 85.7%, 89.7%, and 88.9%, respectively. Results for specificity and accuracy were better when US and SWE were used together than when they were used separately.

According to other research, SWE enhances the specificity, diagnostic reliability, and the ability to differentiate between localized abnormalities and benign ones in ultrasonography, especially in lesions BIRADS-3 and 4. As a result, SWE decreased the quantity of false-positive breast test results.

Our study has the following strength points: Our study addresses a diagnostic challenge: differentiating inflammatory breast lesions from malignancies. Few prior studies have specifically evaluated SWE in this exact context, making our work novel and clinically valuable. We utilized quantitative shear-wave elastography (measuring tissue stiffness in kPa), adding a reproducible and operator-independent parameter to breast imaging. Our results were validated against histopathology, clinical follow-up, and conventional imaging, enhancing the diagnostic credibility of SWE in this setting.

Our study has the following limitations: there were some different limitations of Shear wave Elastography (SWE) that we dealt with in this work that should be addressed: Patient movement, respiratory motion and slight changes in position are potential sources of error “harder” tissues could appear “softer” and thus give rise to false negative findings. Shear wave Elastography (SWE) technique is classically less operator-dependent, although some degree of variability may occur if too much pressure is applied on the probe (elasticity values of kPa or shear wave measurement velocities can be artificially increased), furthermore, inter and intra observer variability may affect the final diagnosis. Intra observer variability may be decreased by training, while inter observer variability needs further studies to be performed to get more standardized results.

## CONCLUSIONS

When assessing breast lesions, shear wave elastography is a useful technique that is used in addition to B mode ultrasonography. If ultrasound features are unclear, SWE imaging could help increase the diagnostic confidence in an indeterminate BI-RADS 3 or 4a lesion. Additionally, it helps distinguish between benign and malignant breast tumors. Consequently, accounting for lesion stiffness may improve positive predictive values and decrease needless benign biopsies. Furthermore, SWE imaging appears to be particularly useful for identifying the cystic content of a breast tumor that appears to be pseudo-solid.

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**Table (S1):** Results of management of the study population

| | Cases | |
|---|---|---|
| Management | **No.** | **%** |
| Mammography | **18** | **50.0** |
| Color Doppler evaluation | **19** | **52.8** |

**Table (S2)**: Relation between SWV and Final Diagnosis

| | **Benign (n=30)** | **Malignant (n=6)** | **p-value** |
|---|---|---|---|
| **Shear wave velocity in the lesion** | | | |
| *Min. – Max.* | 1.2 – 3.7 | 2.7 – 9.1 | <0.001* |
| *Mean ± SD.* | 2.16 ± 0.68 | 7.26 ± 3.02 | |

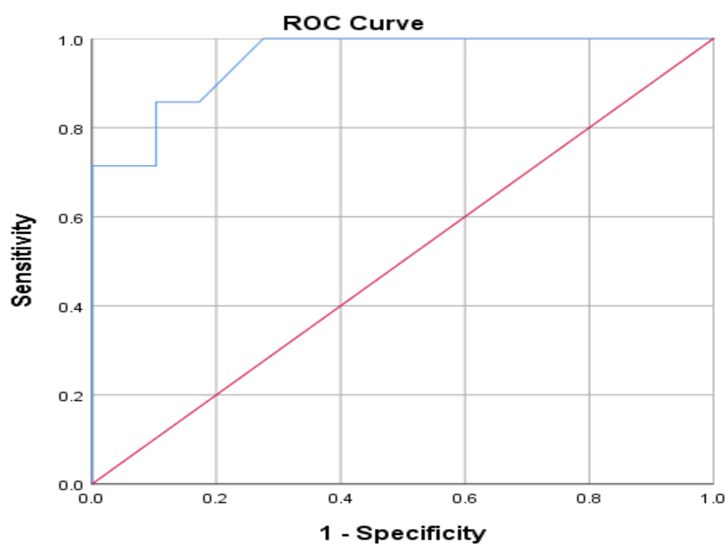


**Figure (S1):** When using SWV to distinguish between benign and malignant tumors, Roc curve analysis is utilized.

A B

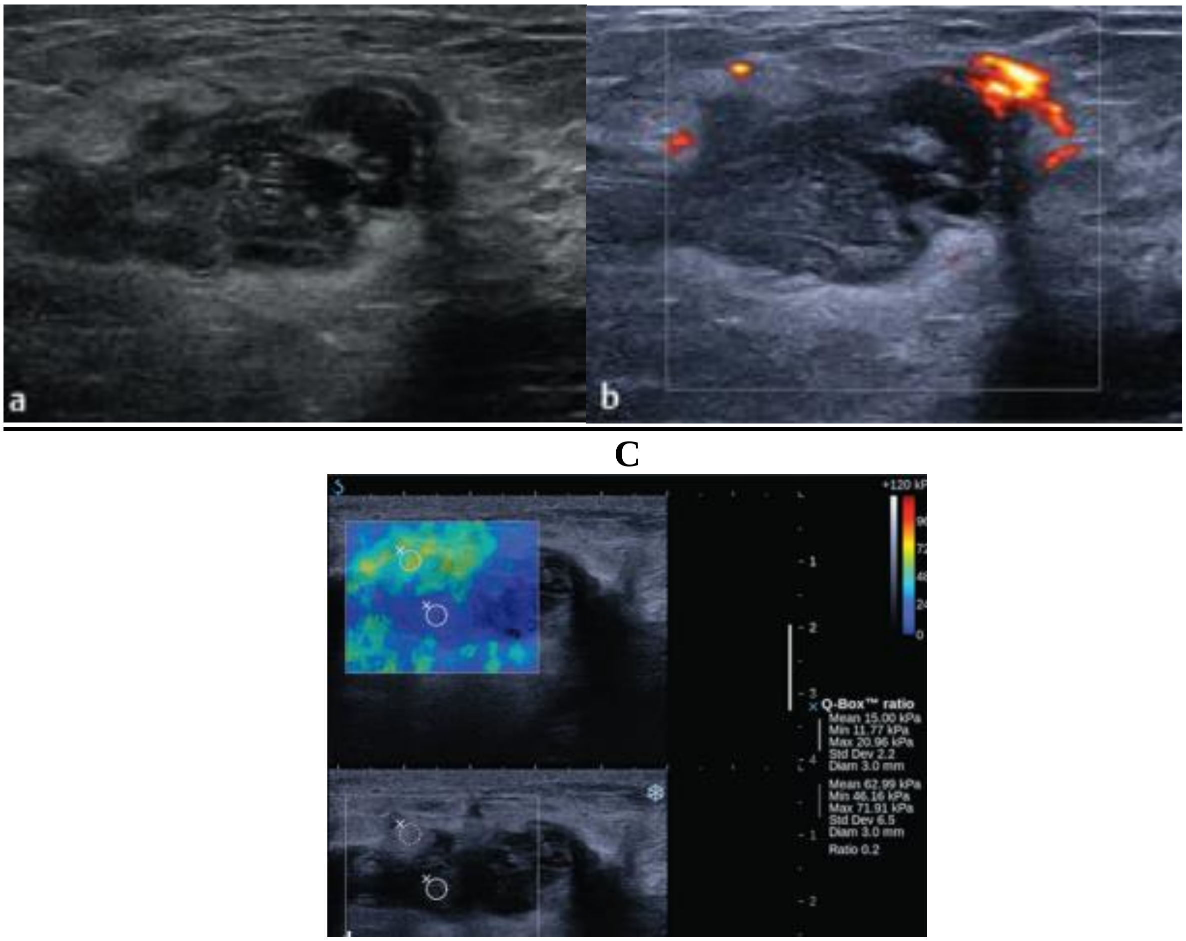


**Figure (S2): (A):** B-mode image of the palpable mass demonstrates a 4 cm irregular, heterogeneous mass corresponding to the mammographic abnormality. **(B):** On power Doppler imaging there is peripheral blood flow but no internal blood flow. **(C):** On shear wave imaging the hypoechoic lesion has a low Vs of 2.2 m/s (15 kPa). The stiff rim noted has a Vs of 4.5 m/s (62 kPa).

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